International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979; Impact Factor: RJIF 5.72
Received: 18-06-2019; Accepted: 20-07-2019
www.allsubjectjournal.com
Volume 6; Issue 9; September 2019; Page No. 164-166

Surface Plasmon resonance of cesium-gold Nano particles using quasi-static approximation

Sanjay Kumar[1], Kuldeep Kumar[2]
[1] Department of Mathematics, Kalindi College, University of Delhi, New Delhi, India
[2] Department of Physics, SGTB Khalsa College, University of Delhi, New Delhi, India

Abstract
In this manuscript the core-shell nano particle under quasi static approximation was modeled for extinction spectra and resonance peak position. The extinction and resonance frequencies were found tunable under the influence of shape, size and dielectric constant of the surrounding media. The Plasmonic peak positions showed a red shift with increasing shell size. Conversely, when shell size is kept fixed with Cesium diameter increasing, a blue shift was observed. The tenability of Plasmonic peak position by varying core-shell dimension or surrounding media in Cs-Au nano-rods has been established here by theoretical evaluation.

Keywords: surface plasmon resonance, core-shell, nano-wire

1. Introduction

Surface Plasmon Resonance (SPR) is the resonance arising due to the collective oscillation of electron cloud on the surface of a metal when excited by incident light. The resonance is achieved when the incident radiation frequency matches with the natural frequency of the oscillating electron cloud. The resonance can be achieved in visible region for noble metals like Au, Ag, Cu and Cs.

SPR has been observed in window panes or ornamental cups (famous Lycurgus Cup) since the time of the Romans [1]. Lycurgus Cup has unique feature of changing color in the light. This cup appears green when illuminated in reflected light and appears red when a light illuminated from inside. Nano crystals of metal silver and gold (70 nm) present in the glass makes the Lycurgus Cup so special [2].

Mie theory of light scattering from dust particles was extended to explain SPR. Mie solve Maxwell's equation and applied boundary conditions on spherical particles whose diameter was comparable to the incident wavelength to find the absorption efficiency (Mie theory) and this theory was extended by Gan's for absorption efficiency of homogeneous elliptical shaped nano-particles [3, 4]. The Dipolar or Quasi-Static Approximation (QSA) is now employed for metal nanoparticles which are far smaller than wavelength of incident light. The QSA has agreement with the Mie theory when nano-shell size is comparable to the wavelength of light [5]. It assumes the applied field to be homogeneous and retarded over the particle volume. Such core-shell systems are of interest because of the tuniability, i.e. ability to choose peak position of SPR changing the shell size. This has potential applications in medicine and detectors. In this article, the optical properties of Cesium (Cs) nanoparticle coated with an Gold (Au) shell were studied.

2. Modeling for core-shell

In this study, let us consider an arbitrarily shaped of the metal nano-particle to be in the form of nanorod, whose length can be considered infinite compared to its; Core-Shell; Nanowire radius of r_2. The core radius is r_1 giving shell dimension of r_2-r_1 (fig 1).

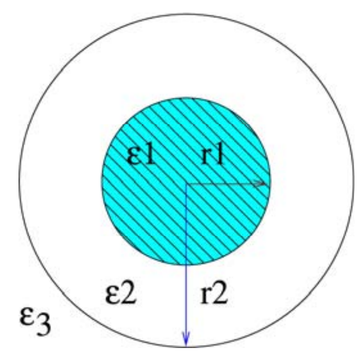

Fig 1: Metal-Metal Core-shell structure for infinite long Nanowire.

SPR due to core-shell structure has been an area of interest for theoretical evaluation. Core- shell has also been experimentally studied by many researchers in the world [7, 8]. The optical properties of metallic nanoparticles depend on their size, shape and surrounding media. The complex dielectric constants of the core, shell and surrounding medium are denoted as ϵ_1 , ϵ_2 and ϵ_3 respectively. The Drude's dielectripc function [9] for metals as a function of frequency is given by

$$\epsilon_D = 1 - \frac{\omega_p^2}{\omega^2 + i\gamma t} \qquad (1)$$

Where, ω_p is a plasma frequency, γ damping constant and t is collision time.

The nano-particle is subjected to the uniform electric field which enables polarization which is proportional to the magnitude of the incident electric field. The oscillation of the incident electric field is along the wire length and the nanowire to be infinitely extended perpendicular to x-y plane. Solving Laplace's equation for metal-metal core-shell nano-structure in the presence of surrounding media, the electric field can be written as

$$E=E_o+\frac{(\epsilon_1-\epsilon_2)(\epsilon_2+\epsilon_3)r_1^2+(\epsilon_1+\epsilon_2)(\epsilon_2-\epsilon_3)r_2^2}{(\epsilon_1-\epsilon_2)(\epsilon_2-\epsilon_3)r_1^2+(\epsilon_1+\epsilon_2)(\epsilon_2+\epsilon_3)r_2^2} \quad (2)$$

where, the polarizability (α) is given as

$$\alpha=4\pi\epsilon_o\frac{(\epsilon_1-\epsilon_2)(\epsilon_2+\epsilon_3)r_1^2+(\epsilon_1+\epsilon_2)(\epsilon_2-\epsilon_3)r_2^2}{(\epsilon_1-\epsilon_2)(\epsilon_2-\epsilon_3)r_1^2+(\epsilon_1+\epsilon_2)(\epsilon_2+\epsilon_3)r_2^2} \quad (3)$$

Scattering theory gives absorption efficiency of infinite long core-shell structures as

$$\alpha_{scat}=\frac{8\pi^2}{\lambda^4\epsilon_o}[\alpha]^2$$

$$\alpha_{ext}=\frac{2\pi}{\lambda\epsilon_o}\Im[\alpha]$$

$$\alpha_{absorption}=\alpha_{ext}-\alpha_{scat} \quad (4)$$

In the dipolar approximation, shell size << λ (wavelength of incident radiation on particle) the extinction is clearly dominated by absorption, i.e. $\alpha_{absorption}=\alpha_{ext}$

In the following section, the SPR peak position in extinction spectra of core-shell nano-rod has been studied due to

- Variation in core radius (r_1) keeping shell size constant (r_2-r_1)
- Variation in shell size (r_2-r_1) keeping core (r_1) constant
- Change in surrounding media has been investigated.

3. Results and Discussion

In the present model, it was assumed that cesium nanowire is coated with thin layer of gold. The variation of optical properties has been studied with the variation of radius of core, shell and dielectric media in which core-shell nanowire embedded.

3.1. Variation in core radius (r_1) keeping shell size constant (r_2-r_1)

Figure 2 shows theoretical simulations for the variation of shell size under the quasi static approximation of Cesium (Cs) coated gold nanorods embedded in a medium with a dielectric constant of air (ϵ_3 = 1). The position of the SPR peak is sensitive to radius of core and the radius change from 1 nm to 18 nm in the present model assuming shell radius constant (r_2 = 10nm) which has been shown in fig 2. it shows blue shift in UV-visible range of the electromagnetic spectrum with increasing core radius.

3.2. Variation in shell size (r_2-r_1) keeping core (r_1) constant

Figure 3 shows theoretical simulations for core-shell morphologies of Cesium coated gold nanorods surrounded by medium with a dielectric constant of air ($_3$ = 1) and keeping core radius constant (r_1 = 100nm). The position of

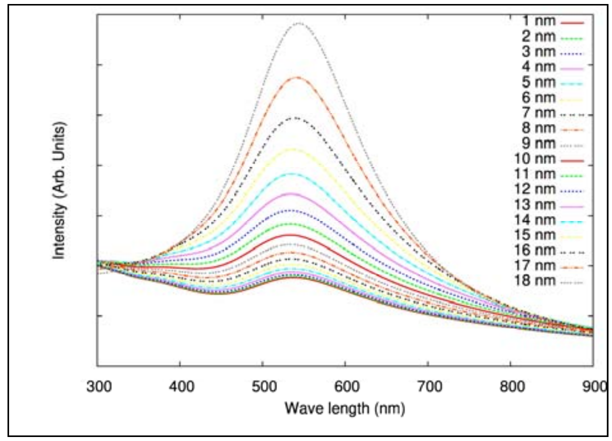

Fig 2: Variation of absorption efficiency with core radius r_1.

The SPR peak is sensitive to radius of shell and it shows red shift with increasing shell radius from 1 nm to 30 nm.

3.3. Effect of surrounding media

Figure 4 shows variation of optical absorption efficiency with dielectric constant of surrounding media. SPR peak position is very sensitive to change in refractive index of the environment of core-shell.

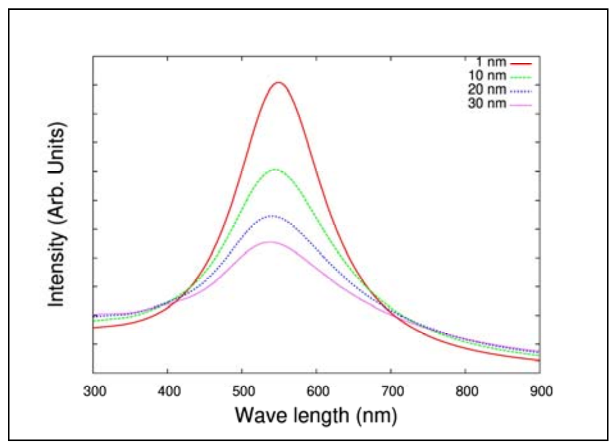

Fig 3: Variation of absorption efficiency with shell radius r_2.

The size dependency of the localized surface plasmon of metallic core {shell can be explained by assuming a size-dependent dielectric function. The dielectric constant of surrounding varies from ϵ_3 =1 to ϵ_3 =3 for our calculations and assuming radius of core (r_1 = 100) and shell radius (r_2-r_1) of the Cs-Au core-shell nano-rod.

4. Conclusions

The magnitude of the shift in resonance peak is a function of geometrical and material parameters as well as position. The tunability of plasmonic peak position in Cs-Au nano-rods has been discussed. The Plasmonic peak positions showed a redshift observed with increasing shell size and a blue shift was observed when shell size is kept fixed with an increase in Cesium diameter. The effect of dielectric media in which core-shell were embedded has been observed the tunablity in plasmonic peak will enable such structures for potential applications in detectors or biosensors for future technology.

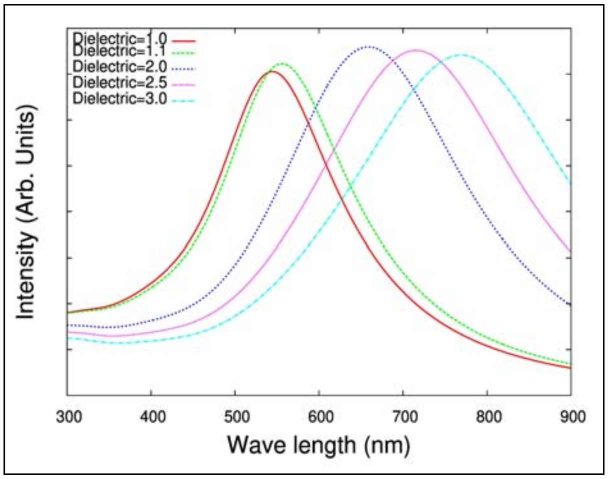

Fig 4: Variation of absorption efficiency of core-shell structure with the dielectric constant of surrounding media.

5. References

1. Kreibig U, Vollmer M. Optical Properties of Metal Clusters, Springer-Verlag, Berlin, 1996.
2. www.thebritishmuseum.ac.uk/science/text/lycurgus/sr-lycurgus-p1-t.html.
3. Bohren CF, Man Hu. Absorption and Scattering of Light by Small Particles, John Wiley & Sons, Inc., New Yark, 1983, 158.
4. Gans R. Ann. Phys. 1915, 47:270.
5. Zhu J, Zhang CL, Appl J. Phys. 2006, 100: 026104.
6. S L Westcott, J B Jackson, C Radlo_ and N J Halas, Phys. Rev. B. 2002, 66:155431.
7. Steinbruck A, Csaki A, Festag G, Fritzsche W. Plasmonics. 2006; 1:79.
8. Chen HM, Liu RS, Jang LY, Lee JF, Hu SF. Chem. Phys. Lett. 2006; 421:118.
9. Kreibig U. J. Phys. F {Metal Phys. 1974, 4:999.